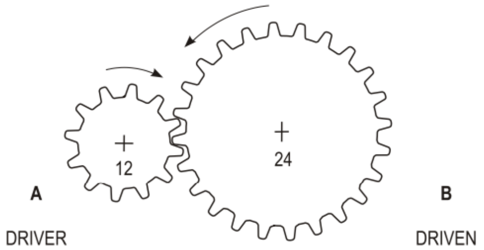
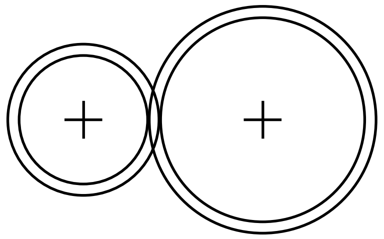
H Mechanisms

Simple gear train

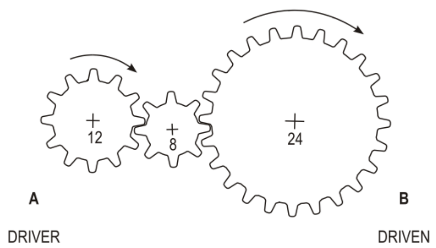
When two or more gears are meshed together they form a simple gear train. The input gear is the driver and the output gear is the driven.



When asked to draw a simple gear train this is how they must be shown.



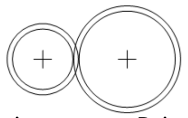
An idler gear is a gear that can be inserted in to a system to allow the driver and driven gear to turn in the same direction. It has no effect on the multiplier ratio or speed of they system.



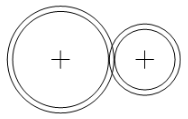
$$MMR = \frac{Driven}{Driver}$$

The movement multiplier ratio (MMR) is used to work out ratio between the size of the driver and driven gears. We then use this ratio as the Velocity Ratio to calculate the input or output speed.

$$VR = \frac{Input\ Speed}{Output\ Speed}$$



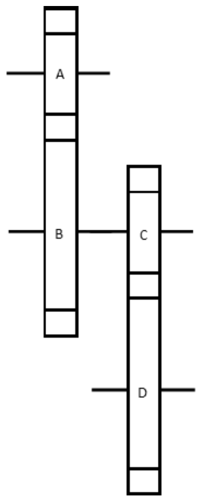
Driver Driven



Driver Driven

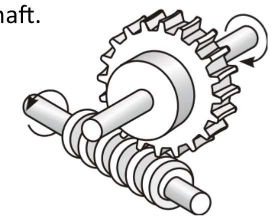
The first gear train creates a decrease in output speed as a large gear turns slower than a smaller one. The second gear train creates a speed increase.

A compound gear system creates a very large change in speed and takes up a small space.



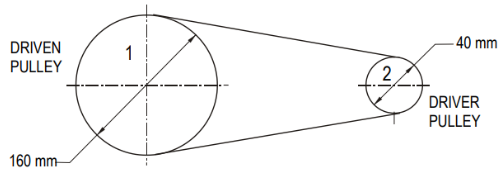
Worm & Wheel

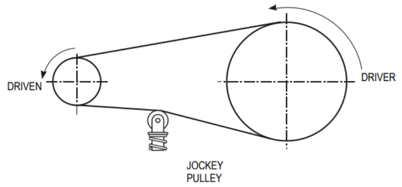
Using a worm and wheel produces a large speed reduction. The worm, which looks rather like a screw thread, is fixed to the driver shaft. It meshes with a worm wheel, which is fixed to the driven shaft. The driven shaft runs at 90 degrees to the driver shaft. When considering the speed changes in most worm gear systems, you can think of the worm as if it were a spur gear with one tooth.



Belt Drive

While gears can be connected together in a simple gear train, if too many gears are used there can be large efficiency losses due to friction. There are two simple means of transmitting rotary motion over relatively large distances. One is to use a belt wrapped around two or more pulleys as shown below. The belt is tightened or tensioned by pulling one of the pulleys out and locking it in place. Pulleys are thin metal discs with a groove cut into the circumference of the disc.





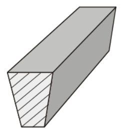
A jockey pulley for tensioning

There are three different types of belts used in pulley systems: V belt, flat belt and toothed belt.

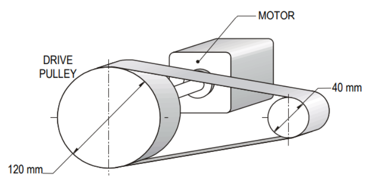
The V belt has an increased surface area pressing against the pulley which helps to increase the torque and reduce slippages.

The flat belt allows slippage when needed but does have a tendency to slip when large loads are added as there is not enough friction between the belt and pulley to keep it in place.

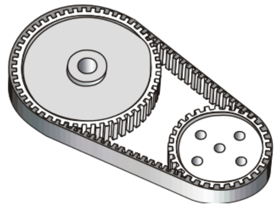
Toothed belts do not allow slippage.



Vee belt for extra grip

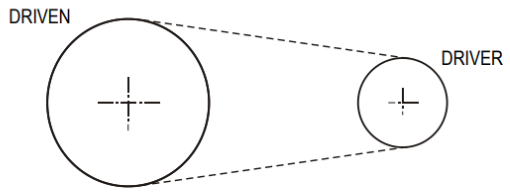


Belt-and-pulley system



Chain Drive

Even when belt drives are properly tensioned they can still slip. To prevent slippage a chain drive is used.



Couplings

The most common coupling uses are:

- Connecting two shafts together to transmit power, torque or movement.
- To allow for systems to be disconnected for repairs or alterations, such as a motor and a generator.
- If shafts are not perfectly aligned, the coupling will be able to compensate for this without damage to the system.
- Reduces shock loads between shafts.
- To connect the driver and driven parts of systems.

Aligned Shafts

Where shafts are in line with each other they are joined either with a flanged coupling or a muff coupling. All couplings must be 'keyed' to the shafts they are joining to give a positive drive.

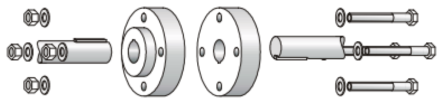


Figure 1(a): flange coupling

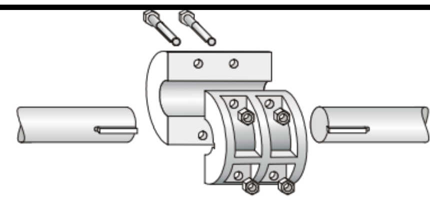


Figure 1(b): muff coupling

Non-aligned Shafts

Where shafts meet at a slight angle, some method of compensating for misalignment must be used. Where the misalignment is small, a flexible coupling (flexi-coupling), using either rubber or a mixture of rubber and steel, is used. The rubber is flexible enough to compensate for small changes in angle.

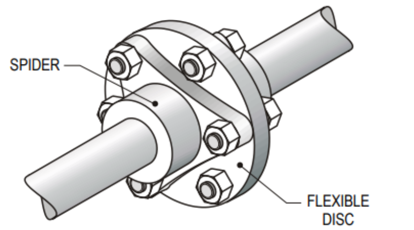


Figure 2: flexi-coupling

When the alignment is more than a few degrees out, a universal joint is used. A universal joint can transmit motion through an angle of 20 degrees. Figure 3 shows Hooke's universal joint. The two yokes are free to pivot on the central 'spider'. Modern universal joints use needle roller-bearings between the spider and the yokes.

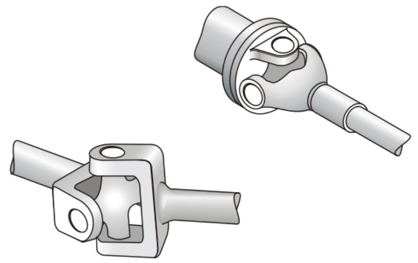


Figure 3: universal joints

Clutches

Clutches are devices that allow two rotating shafts to be connected and disconnected. There are two types of clutch, the positive clutch and the friction clutch. A dog clutch is a positive clutch. This has four interlocking blocks (dogs) on one shaft that can be interlocked with four dogs on the other shaft. When the clutch is engaged, the two dogs are interlocked and the drive shaft rotates the driven shaft. When the clutch is disengaged, the two shafts are separated. In clutch systems, the two shafts must be carefully aligned. Positive-drive clutch es require the drive shaft to be stationary when the tw clutch plates are brought together. Friction clutches ca be engaged and disengaged while both shafts are still turning. Friction clutches rely on the friction between the plates to transmit the power from one shaft to another. Figure 2 shows a simple example of a friction clutch.

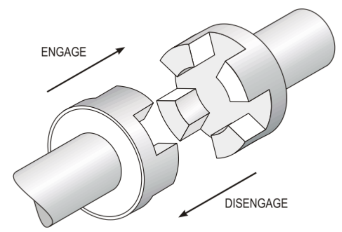


Figure 1: a dog clutch

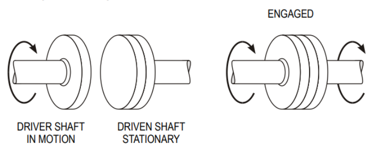


Figure 2: a simple friction clutch

Friction

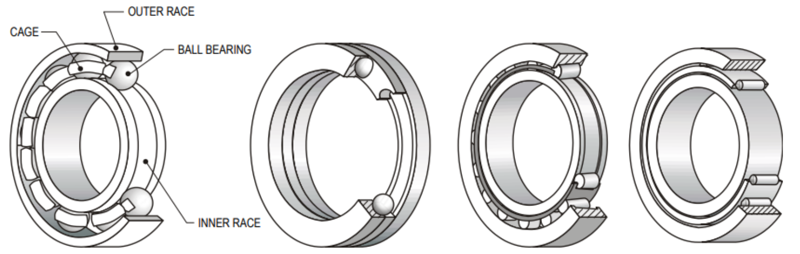
Lubrication

In all drive systems there is friction which produces heat. This can cause the gears to expand which causes damage to the drive system. To help reduce this you can lubricate the system using oil or grease which in turn increases the efficiency of the drive system. Another option is to use bearings as these can be easily replaces when worn out instead of damaging and replacing the whole drive system.

Bearings

Ball-and-roller bearings

Ball and roller bearings change the action of rubbing to that of rolling. Ball and roller bearings use hardened steel balls or rollers, which rotate inside an inner and outer case. The outer case or 'race' presses into a housing; the inner race is a press fit on the shaft. These bearings are used in high-speed, high-force applications.



Ball Thrust ball Roller Needle roller

Journal bearings

Journal bearings are made from a variety of materials: the most common are bronze and white metal. Bronze is used where slow, heavy loads are carried. White metal, an alloy of tin, copper and antimony, which is soft and melts when overheated, is used in systems with light loads. Plastic and nylon bearings are also very common.

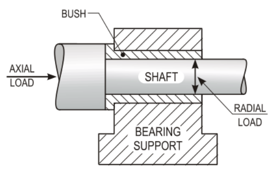


Figure 2: combined thrust and journal bearing

Split bearings

As bearings are designed to wear, it stands to reason that they must be able to be removed and replaced. When the bearing support is at the start or end of a shaft, it is simple to remove and replace it. However, when a shaft is very long, it may be supported at several points along its length. To make it easy to remove and replace bearings, split bearings are used. When the bearing wears, the bearing housing can be separated by removing the two nuts. The bearing shells can then be removed and replaced. Notice that the inside of the shells has a groove. This groove is normally fed by a reservoir of oil, which helps to lubricate the shaft and bearing, thus reducing friction. A car big end is a common example.

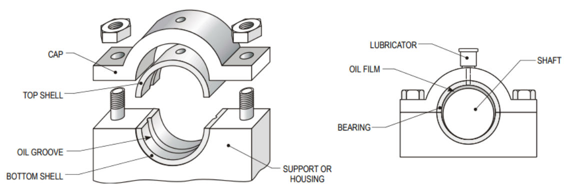


Figure 3: a split bearing

Torque

$$T = Fr$$

Torque is the force required to turn an object.

Torque is measured in Nm.

Force is measured in N.

Distance is measured in m.

Mechanical Power

$$P = Fv$$

Mechanical power is the power created when a system turns.

Power is measured in Watts (W).

Force is measured in Newtons (N).

Velocity (or speed) is measured in metres per second (ms^{-1}).

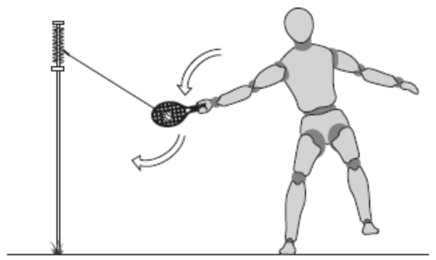
OR

$$P = 2\pi nT$$

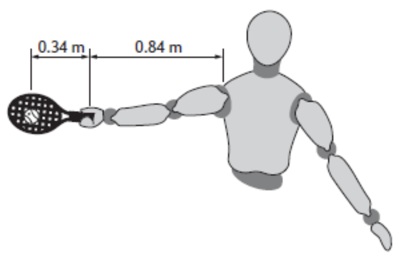
n is the rotational speed per second (rev sec^{-1}).

T is measured in Newton metres (Nm).

3. In a popular garden game, a tennis ball attached to a pole by a length of rope is hit with a racquet to swing around for another player to hit back.



One player has an arm length of 0.84 m and the ball hits the racquet at a further distance of 0.34 m as shown below.

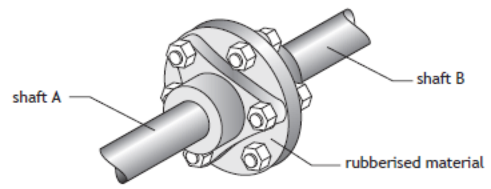


(a) Calculate the force that this player strikes the ball with to produce a torque of 295 Nm. 2

r = 0.84 + 0.34
r = 1.18 m

F = T/r
F = 295 / 1.18
F = 250 N (2 sf)

4. Flexible couplings can be used rather than rigid couplings to connect two shafts. An example of a flexible coupling is shown.



(a) Describe two advantages of using flexible couplings rather than rigid couplings to connect shaft A and shaft B. 2

Advantage 1 Can be used where shafts intersect at a slight angle.

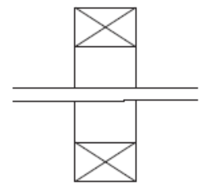
Advantage 2 Dampens vibrations or reduces shocks that shafts are subjected to.

(b) State the name of another mechanical method of joining two shafts together to transmit rotational motion. 1

Clutch.

Universal joint.

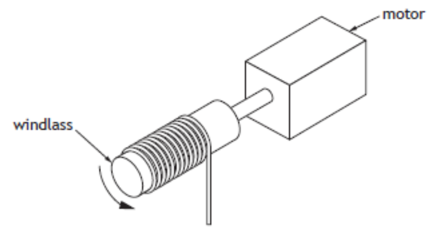
A typical graphic symbol used by engineers to represent a bearing is shown below.



(c) Describe one function of a bearing in a drive system. 1

It supports the weight of the shaft while allowing the shaft to rotate.
Reduces contact surface area and therefore energy loss.
Reduces contact surface area so reduces friction.
Reduces friction and therefore saves wear on the shaft.
Replace the worn bearing instead of the parent part.
To enable a shaft to smoothly rotate.
To assist with smooth rotation of moving components

A motor-driven winch system is used for lifting construction materials with up to 12,000 kg of mass. The windlass, with 320 mm diameter, rotates at 12 revolutions per minute.



(b) Calculate the mechanical power required by this motor. 5

F = 12000 × 9.8
= 117600 N

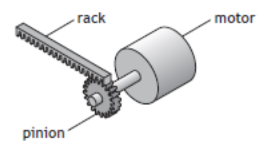
r = 0.320/2
= 0.160 m

T = 117600 × 0.16
= 18816 Nm

n = 12/60
= 0.2 revs sec^{-1}

P = $2\pi nT$
= $2\pi \times 0.2 \times 18816$
P = 23644.88295
P = **24 kW (2 sf)**

Part of the design involves rotary motion, from a motor, transforming into linear motion.



The pinion gear has 24 teeth and the pitch of the teeth on the rack is 3·0 mm.

The rack is required to move 2·75 m in three seconds.

(d) Calculate the required speed of the motor. 3

Distance of 1 rev of pinion
24 × 3·0 = 72 mm

No revolutions required = 2750 / 72
= 38·19444444 revolutions

Speed of motor = (38·19444444/3)
= 12·73148148
= **13 rev sec^{-1} (2sf)**